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(54) **ORGANIC ELECTROLUMINESCENT ELEMENT AND LIGHT EMITTING DEVICE WITH OPTICAL PATH CONTROL LAYER**

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H01L 51/52 (2006.01)
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CPC ***H01L 51/5275*** (2013.01); ***H01L 51/5012*** (2013.01); ***H01L 51/5265*** (2013.01)

(58) **Field of Classification Search**
CPC H01L 51/5275; H01L 51/5012; H01L 51/5265
See application file for complete search history.

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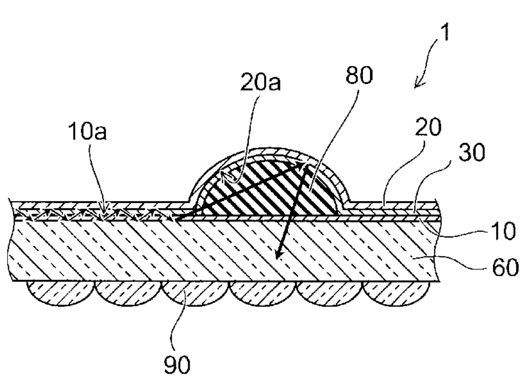
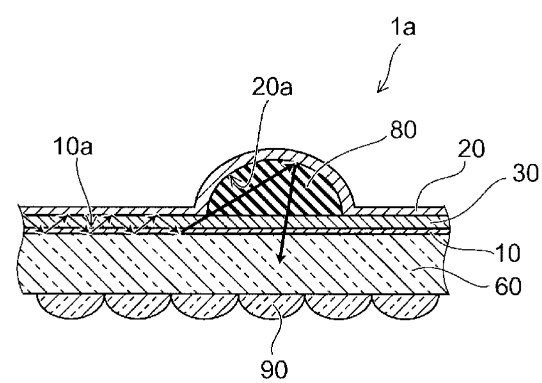
(57) **ABSTRACT**

According to one embodiment, an organic electroluminescent element includes a first electrode, a second electrode provided opposite to the first electrode, an organic light emitting layer provided between the first electrode and the second electrode, and a protrusion. The protrusion is provided at least one of between the first electrode and the organic light emitting layer and between the organic light emitting layer and the second electrode.

18 Claims, 10 Drawing Sheets





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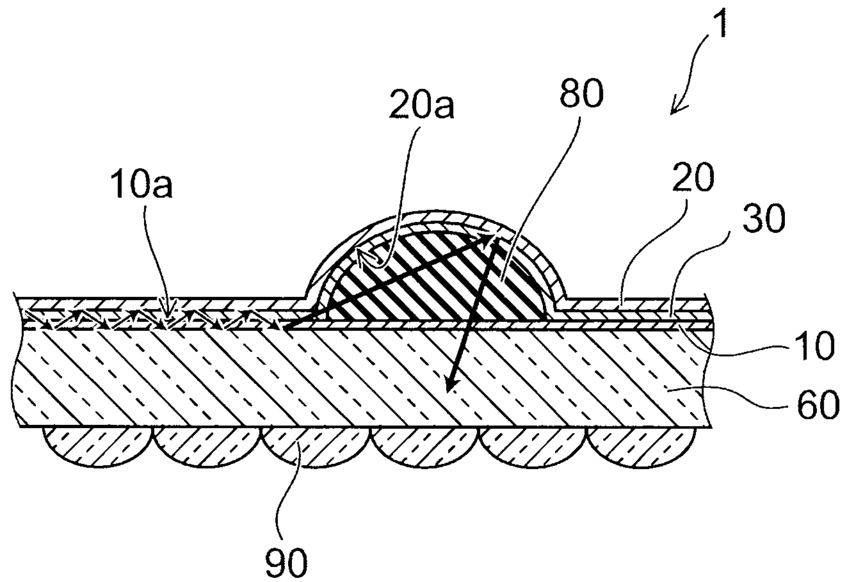


FIG. 1A

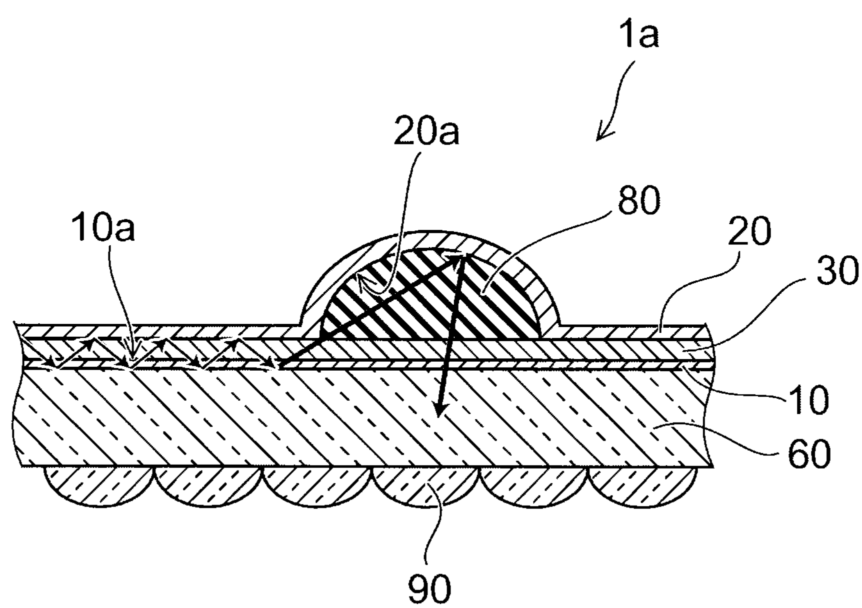


FIG. 1B

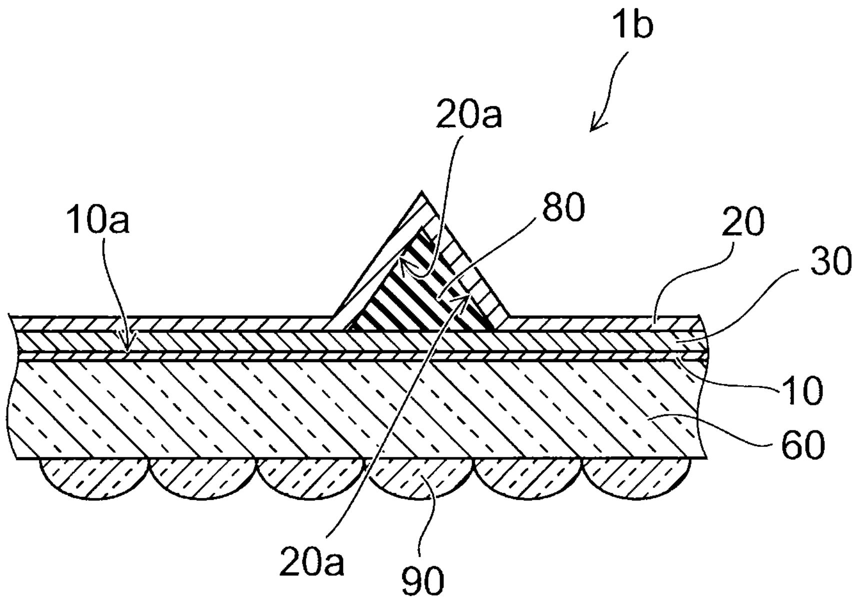
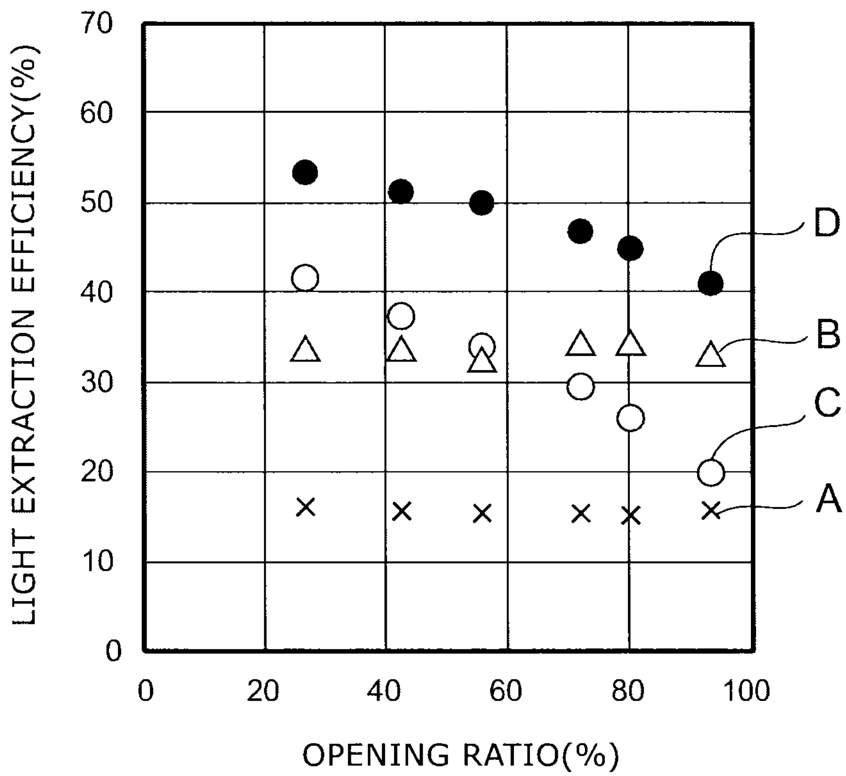


FIG. 2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70
60
50
40
30
20
10
0
0
20
40
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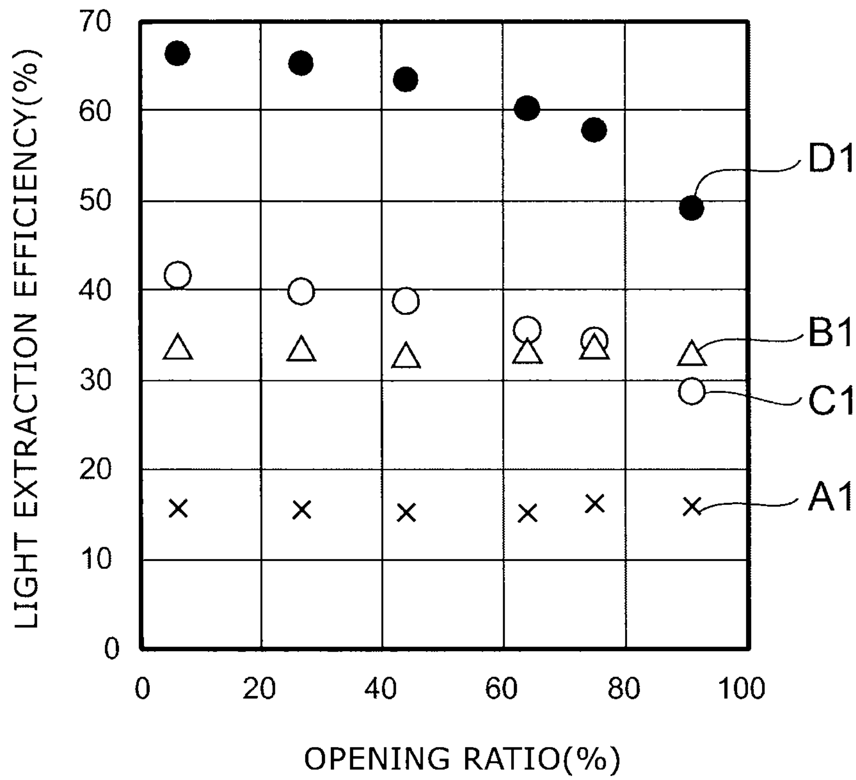
OPENING RATIO(%)
D
B
C
A

FIG. 3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B1
C1
A1

FIG. 4

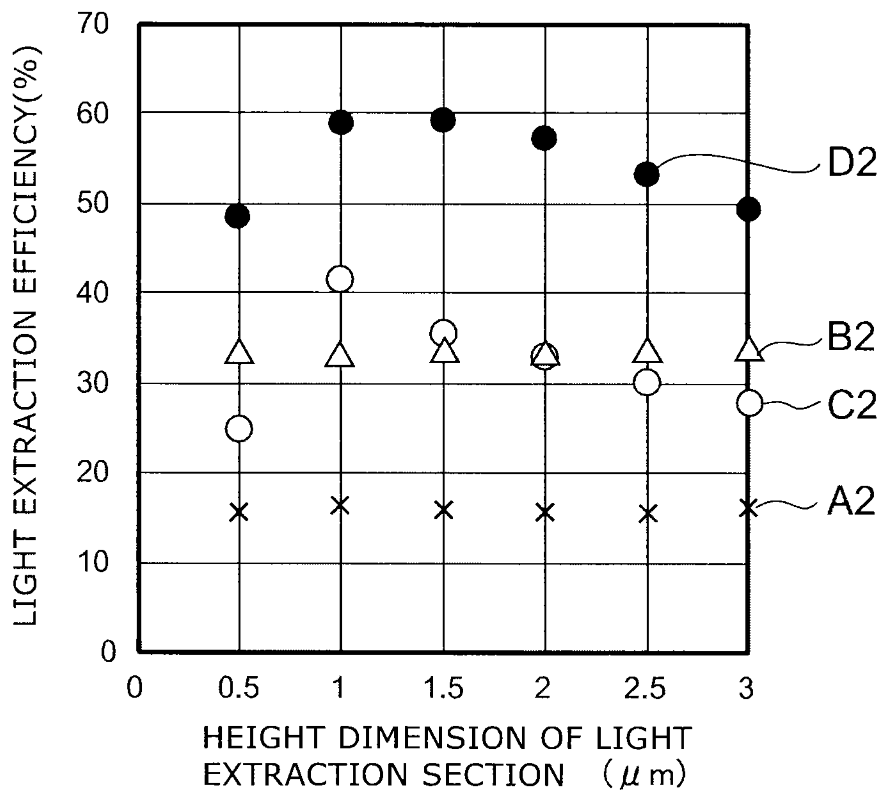

70
60
50
40
30
20
10
0
LIGHT EXTRACTION EFFICIENCY(%)
0
0.5
1
1.5
2
2.5
3
HEIGHT DIMENSION OF LIGHT EXTRACTION SECTION (μm)
D2
B2
C2
A2

FIG. 5

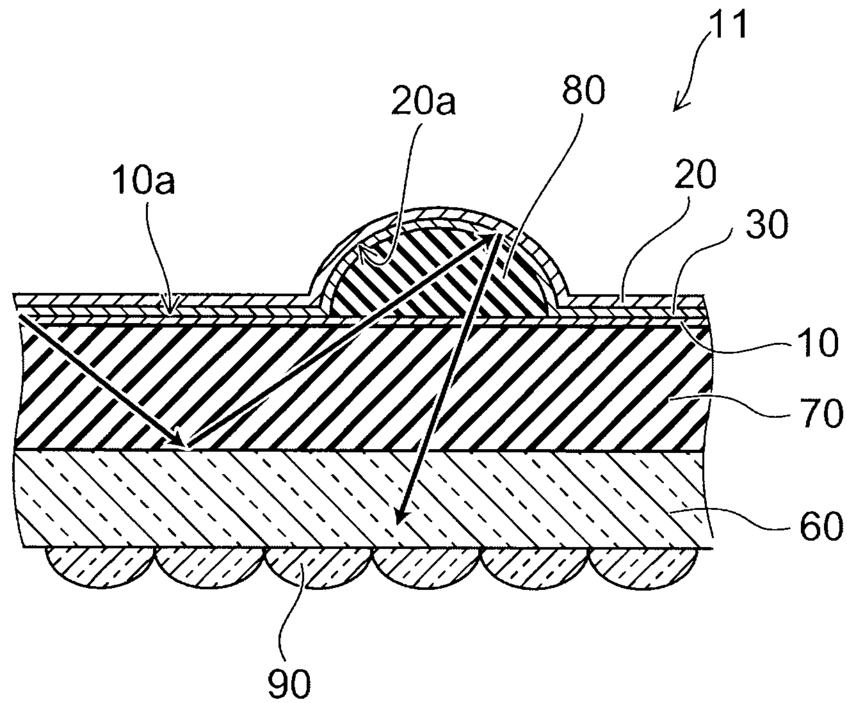


FIG. 6A

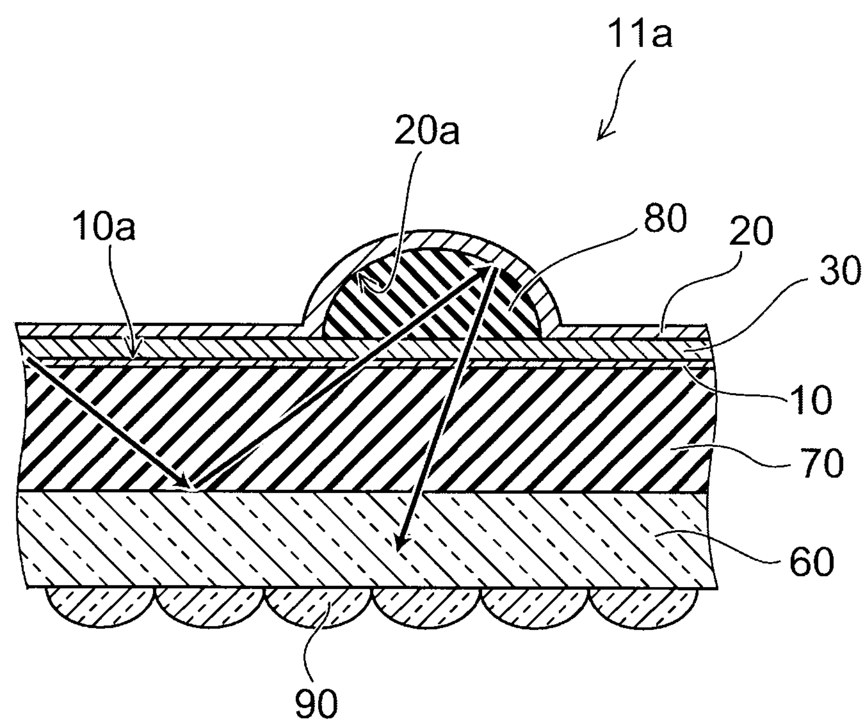
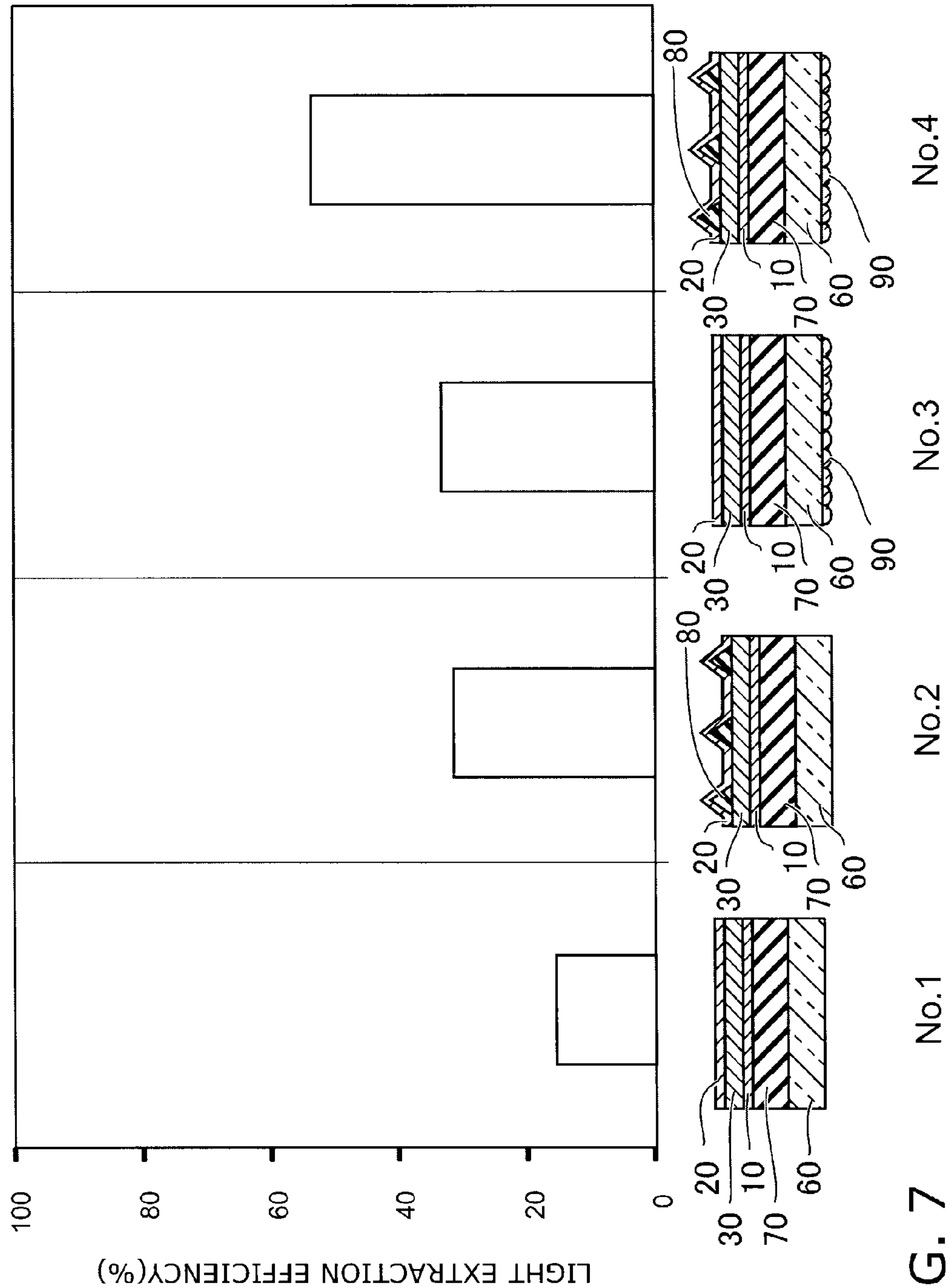


FIG. 6B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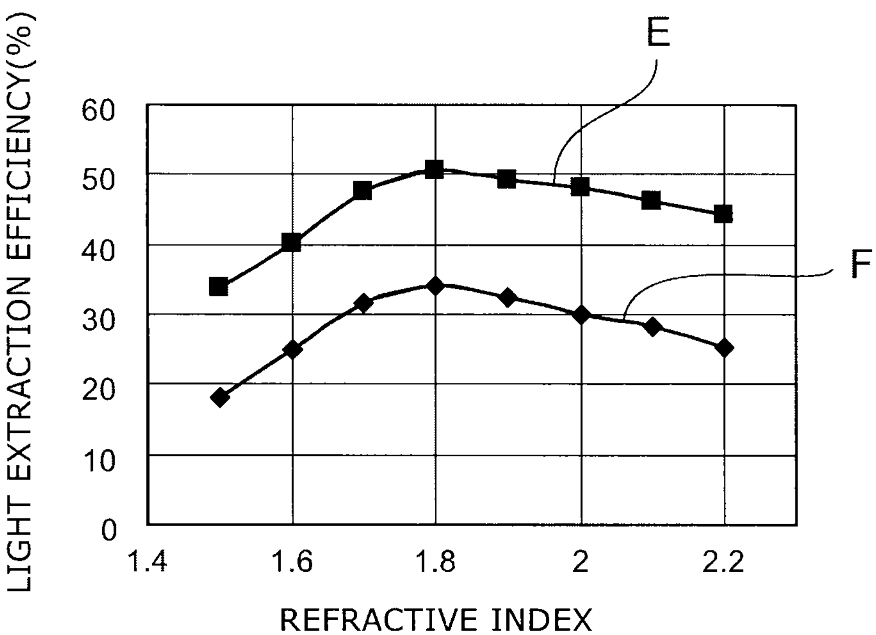
0
20
40
60
80
100
No.1
No.2
No.3
No.4
10
20
30
60
70
80
90

FIG. 7


E
F
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50
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10
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1.6
1.8
2
2.2
LIGHT EXTRACTION EFFICIENCY(%)
REFRACTIVE INDEX

FIG. 8

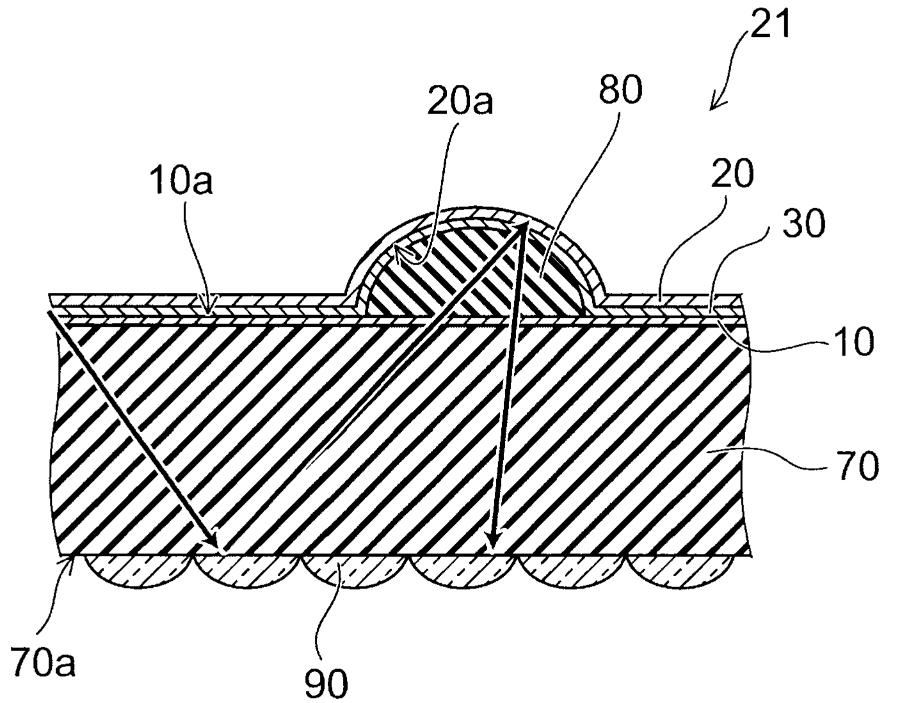

FIG. 9A

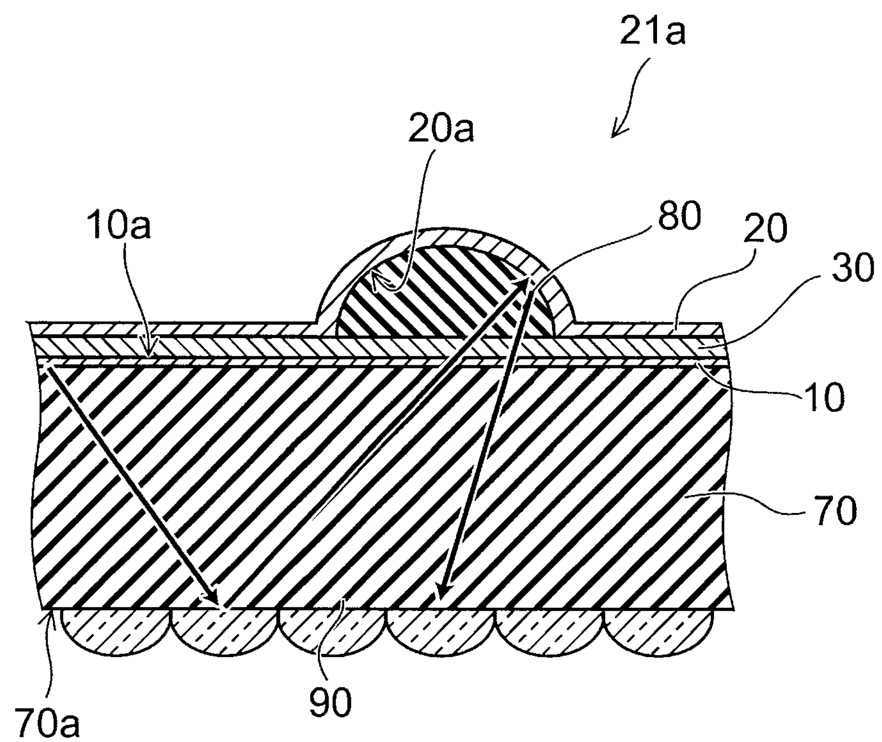

FIG. 9B

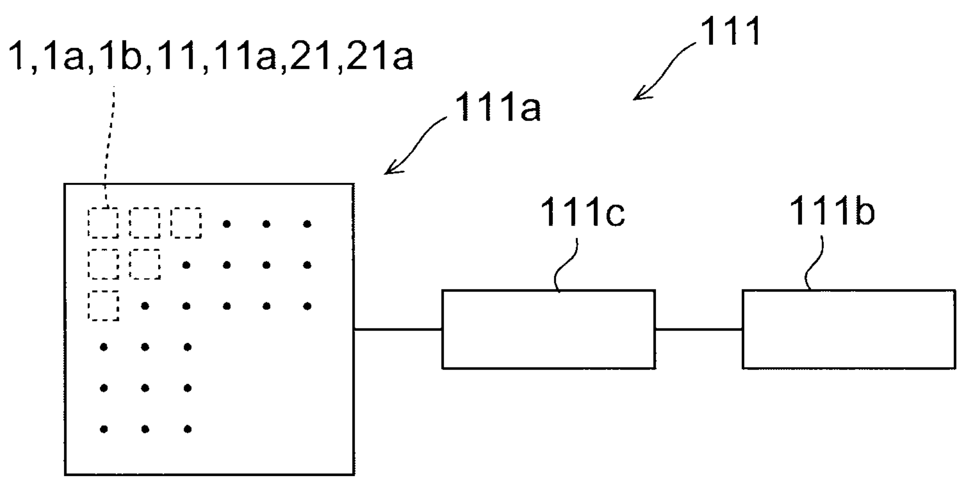

FIG. 10

ORGANIC ELECTROLUMINESCENT ELEMENT AND LIGHT EMITTING DEVICE WITH OPTICAL PATH CONTROL LAYER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2012-211420, filed on Sep. 25, 2012, and PCT Patent Application PCT/JP2013/004804, filed on Aug. 8, 2013; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to an organic electroluminescent element and a light emitting device.

BACKGROUND

The organic electroluminescent element includes a cathode electrode, an anode electrode, and an organic light emitting layer provided between the cathode electrode and the anode electrode.

In the organic electroluminescent element, a voltage is applied between the cathode electrode and the anode electrode. Thus, electrons are injected from the cathode electrode into the organic light emitting layer, and holes are injected from the anode electrode into the organic light emitting layer. The injected electrons and holes are recombined, and excitons are generated by the recombination. When the exciton undergoes radiative deactivation, light is generated.

In such an organic electroluminescent element, improvement in light extraction efficiency is desired.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A and **1**B are schematic sectional views illustrating organic electroluminescent elements according to a first embodiment;

FIG. **2** is a schematic sectional view for illustrating an alternative shape of a protrusion **80**;

FIG. **3** is a graph illustrating the light extraction efficiency in the case of providing a protrusion **80** shaped like a hemisphere;

FIG. **4** is a graph illustrating the light extraction efficiency in the case of providing a protrusion **80** shaped like a quadrangular prism;

FIG. **5** is a graph illustrating the light extraction efficiency in the case of providing a protrusion **80** shaped like a quadrangular prism;

FIGS. **6**A and **6**B are schematic sectional views illustrating organic electroluminescent elements according to a second embodiment;

FIG. **7** is a graph for illustrating the light extraction efficiency;

FIG. **8** is a graph for illustrating the relationship between the refractive index of the protrusion **80** and the light extraction efficiency;

FIGS. **9**A and **9**B are schematic sectional views illustrating organic electroluminescent elements according to a third embodiment; and

FIG. **10** is a schematic view for illustrating a light emitting device **111**.

DETAILED DESCRIPTION

According to one embodiment, an organic electroluminescent element includes a first electrode, a second electrode provided opposite to the first electrode, an organic light emitting layer provided between the first electrode and the second electrode, and a protrusion. The protrusion is provided at least one of between the first electrode and the organic light emitting layer and between the organic light emitting layer and the second electrode.

Various embodiments will be described hereinafter with reference to the accompanying drawings.

The drawings are schematic or conceptual. The relationship between the thickness and the width of each portion, and the size ratio between the portions, for instance, are not necessarily identical to those in reality. Furthermore, the same portion may be shown with different dimensions or ratios depending on the figures.

In the present specification and the drawings, components similar to those described previously with reference to earlier figures are labeled with like reference numerals, and the detailed description thereof is omitted appropriately.

First Embodiment

FIGS. **1**A and **1**B are schematic sectional views illustrating organic electroluminescent elements according to a first embodiment.

FIG. **1**A shows the case where the protrusion **80** described later is provided between a first electrode **10** and an organic light emitting layer **30**.

FIG. **1**B shows the case where the protrusion **80** is provided between an organic light emitting layer **30** and a second electrode **20**.

As shown in FIGS. **1**A and **1**B, the organic electroluminescent element **1**, **1***a* includes the first electrode **10**, the second electrode **20**, an organic light emitting layer **30**, and a protrusion **80**.

The first electrode **10** is transmissive to light emitted from the organic light emitting layer **30**.

The first electrode **10** functions as e.g. an anode. The thickness dimension of the first electrode **10** can be set to e.g. 50 nanometers (nm) or more.

The first electrode **10** includes e.g. an oxide containing at least one element selected from the group consisting of In, Sn, Zn, and Ti. The first electrode **10** can be made of e.g. a film (such as NESA) fabricated from a conductive glass containing such as indium oxide, zinc oxide, tin oxide, indium tin oxide (ITO) film, fluorine-doped tin oxide (FTO), and indium zinc oxide. The refractive index of the first electrode **10** is e.g. 1.7 or more and 2.2 or less.

The second electrode **20** is provided opposite to the first electrode **10**.

The second electrode **20** is reflective to light emitted from the organic light emitting layer **30**. The light reflectance of the second electrode **20** is higher than the light reflectance of the first electrode **10**. In this specification, the state of having a light reflectance higher than the light reflectance of the first electrode **10** is referred to as being reflective.

The second electrode **20** functions as e.g. a cathode. The thickness dimension of the second electrode **20** can be set to e.g. 5 nanometers (nm) or more. In the case of 5 nanometers (nm) or more, part of the light emitted from the organic light emitting layer **30** can be reflected, and a current can be effectively supplied to the organic light emitting layer **30**.

The second electrode **20** contains e.g. at least one of aluminum and silver. For instance, the second electrode **20** is made of an aluminum film. Alternatively, the second electrode may be made of an alloy of silver and magnesium. Furthermore, calcium may be added to this alloy.

The organic light emitting layer **30** is provided between the first electrode **10** and the second electrode **20**. The organic light emitting layer **30** emits e.g. light containing a component of the wavelength of visible light. For instance, the light emitted from the organic light emitting layer **30** is substantially white light. That is, the light emitted out from the organic electroluminescent element **1**, **1***a* is white light. Here, "white light" is substantially white, and includes light in such as red-tinged, yellow-tinged, green-tinged, blue-tinged, and violet-tinged white.

The thickness dimension of the organic light emitting layer **30** can be set to e.g. 5 nanometers (nm) or more.

The refractive index of the organic light emitting layer **30** is e.g. 1.7 or more and 2.2 or less.

The organic light emitting layer **30** can be made of a material such as Alq_3 (tris(8-hydroxyquinolinato)aluminum), F8BT (poly(9,9-dioctylfluorene)-co-benzothiadiazole), and PPV (poly(p-phenylene vinylene)).

Furthermore, the organic light emitting layer **30** can be made of e.g. a mixed material of a host material and a dopant added to the host material. The host material can be based on such as CBP (4,4'-N,N'-bis(carbazolyl)-1,1'-biphenyl), BCP (2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline), TPD (tetraphenyldiaminobiphenyl), PVK (polyvinyl carbazole), and PPT (poly(3-phenylthiophene)). The dopant material can be based on such as Flrpic (iridium(III) bis(4,6-diflurophenyl)-pyridinato-N,C2'-picolinate), $Ir(ppy)_3$ (tris(2-phenylpyridine)iridium), and Flr6 (bis(2,4-difluorophenylpyridinato)-tetrakis(1-pyrazolyl)borate iridium(III)).

Furthermore, the organic electroluminescent element **1**, is can further include a first functional layer and a second functional layer, not shown, as necessary.

The first functional layer, not shown, is provided between the organic light emitting layer **30** and the first electrode **10**. The thickness dimension of the first functional layer can be set to e.g. 1 nanometer (nm) or more and 500 nanometers (nm) or less.

When the first functional layer is provided, the protrusion **80** is provided between the first electrode **10** and the first functional layer.

The first functional layer functions as e.g. a hole injection layer. The first functional layer functioning as a hole injection layer contains such as PEDPOT:PPS (poly(3,4-ethylenedioxythiophene)-poly(styrene sulfonate)), CuPc (copper phthalocyanine), and MoO_3 (molybdenum trioxide).

The first functional layer functions as e.g. a hole transport layer. The first functional layer functioning as a hole transport layer contains such as α-NPD (4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl), TAPC (1,1-bis[4-[N,N-di(p-tolyl)amino]phenyl]cyclohexane), m-MTDATA (4,4',4"-tris[phenyl(m-tolyl)amino]triphenylamine), TPD (bis(3-methylphenyl)-N,N'-diphenylbenzidine), and TCTA (4,4',4"-tri(N-carbazoyl)triphenylamine).

The first functional layer may be made by stacking a layer functioning as a hole injection layer and a layer functioning as a hole transport layer.

The second functional layer, not shown, is provided between the organic light emitting layer **30** and the second electrode **20**. The thickness dimension of the second functional layer can be set to e.g. 1 nanometer (nm) or more and 500 nanometers (nm) or less.

The second functional layer functions as e.g. an electron transport layer. The second functional layer contains such as Alq_3 (tris(8-quinolinolato)aluminum(III)), BAlq (bis(2-methyl-8-quinolinolato-N1,O8)-(1,1'-biphenyl-4-olato)aluminum), Bphen (bathophenanthroline), and 3TPYMB (tris[3-(3-pyridyl)mesityl]borane).

The second functional layer functions as e.g. an electron injection layer. In this case, the second functional layer contains such as lithium fluoride, cesium fluoride, and lithium quinoline complex.

Alternatively, the second functional layer may be made by stacking a layer functioning as an electron transport layer and a layer functioning as an electron injection layer. In this case, the layer functioning as an electron injection layer is intended to improve the electron injection characteristics. The layer functioning as an electron injection layer is provided between the layer functioning as an electron transport layer and the second electrode **20**.

The protrusion **80** is provided between the first electrode **10** and the second electrode **20**.

As shown in FIG. **1**A, in the organic electroluminescent element **1**, the protrusion **80** is provided between the first electrode **10** and the organic light emitting layer **30**.

As shown in FIG. **1**B, in the organic electroluminescent element **1***a*, the protrusion **80** is provided between the organic light emitting layer **30** and the second electrode **20**.

If the protrusion **80** is provided between the first electrode **10** and the second electrode **20**, the light extraction efficiency can be improved. In this case, the light extraction efficiency can be improved whether by providing the protrusion **80** between the first electrode **10** and the organic light emitting layer **30** or by providing the protrusion **80** between the organic light emitting layer **30** and the second electrode **20**.

Details on the improvement in the light extraction efficiency will be described later.

Here, in the case where the protrusion **80** is provided between the organic light emitting layer **30** and the second electrode **20**, the protrusion **80** is formed on the organic light emitting layer **30**. For instance, the protrusion **80** having a width dimension of 1 micrometer (μm) or more and 20 micrometers (μm) or less can be formed by photolithography technique and the like. For instance, the protrusion **80** having a width dimension of 20 micrometers (μm) or more and 1000 micrometers (μm) or less can be formed by vacuum evaporation technique or sputtering technique using a metal mask. In the case where the protrusion **80** is formed on the organic light emitting layer **30**, the organic light emitting layer **30** can be formed on a flat first electrode **10**. Thus, the organic light emitting layer **30** is made flat. This facilitates the formation of the protrusion **80**. However, use of photolithography technique or sputtering technique may damage the organic light emitting layer **30**. This may require countermeasures such as providing a protective layer before forming the protrusion **80**.

In contrast, in the case where the protrusion **80** is provided between the first electrode **10** and the organic light emitting layer **30**, the protrusion **80** is formed on the first electrode **10**, and the organic light emitting layer **30** is formed so as to cover the first electrode **10** and the protrusion **80**. For instance, the protrusion **80** having a width dimension of 1 micrometer (μm) or more and 20 micrometers (μm) or less can be formed by photolithography technique and the like. For instance, the protrusion **80** having a width dimension of 20 micrometers (μm) or more and 1000 micrometers (μm) or less can be formed by vacuum evaporation technique or sputtering technique using a metal mask. In this case, the protrusion **80** can be formed before forming the organic light emitting layer **30**. Thus, there occurs no damage to the organic light emitting layer **30**.

The protrusion **80** can be provided in a plurality and spaced from each other.

The protrusion **80** is transmissive to light emitted from the organic light emitting layer **30**.

Furthermore, the protrusion **80** is conductive or insulative.

The protrusion **80** can be formed from a conductive material being sufficiently conductive and having higher conductivity by one or more orders of magnitude (in units of S/m) than the organic light emitting layer **30**. Then, the protrusion **80** functions as part of the first electrode **10** or the second electrode **20**. In this case, light emission occurs also in the organic light emitting layer **30** overlapping the portion in which the protrusion **80** is formed. Thus, there is no decrease in the light emitting area due to the provision of the protrusion **80**. Furthermore, in the case where the protrusion **80** being conductive is provided between the organic light emitting layer **30** and the second electrode **20**, the organic light emitting layer **30** is formed on a flat first electrode **10**. Thus, there occurs no problem such as short circuit.

On the other hand, if the protrusion **80** is insulative, then although the light emitting area decreases, there occurs no problem such as short circuit in either case where the protrusion **80** is provided between the first electrode **10** and the organic light emitting layer **30** or between the organic light emitting layer **30** and the second electrode **20**. This facilitates the fabrication of the organic electroluminescent element.

The refractive index of the protrusion **80** can be made comparable to the refractive index of the organic light emitting layer **30**. If the refractive index of the protrusion **80** is comparable to the refractive index of the organic light emitting layer **30**, light can be smoothly introduced into the protrusion **80** from the organic light emitting layer **30** side.

For instance, the refractive index of the protrusion **80** is denoted by n, and the refractive index of the organic light emitting layer **30** is denoted by n_1. Then, the refractive indices can be set as $n_1 \times 0.9 \le n \le n_1 \times 1.1$.

The protrusion **80** can be made of e.g. SiN_x. The "x" means integer.

Alternatively, the protrusion **80** can be made of e.g. a polymer resin such as an acrylic resin (e.g., refractive index=1.49) and a triazine-based resin (e.g., refractive index=1.7 to 1.8).

In the case of using a polymer resin, the refractive index can be adjusted by dispersing a plurality of particles having higher refractive index than the polymer resin inside the polymer resin. A particle having higher refractive index than the polymer resin is a particle made of such as a titanium oxide (e.g., refractive index=2.7) and a zirconium oxide.

For instance, in the case of using an acrylic resin having a refractive index of 1.49, particles made of titanium oxide having a refractive index of 2.7 can be used. Then, the proportion of the particles to the acrylic resin can be set to approximately 20%. Then, the refractive index of the protrusion **80** can be set to approximately 1.7. Alternatively, the proportion of the particles to the acrylic resin can be set to approximately 60%. Then, the refractive index of the protrusion **80** can be set to approximately 2.2.

Thus, by changing the proportion of the particles to the polymer resin, the refractive index of the protrusion **80** can be made comparable to the refractive index of the organic light emitting layer **30**.

The protrusion **80** is projected from the first electrode **10** or the organic light emitting layer **30** toward the second electrode **20** side. The protrusion **80** is shaped so that the cross-sectional area in the direction parallel to the surface **10***a* of the first electrode **10** gradually decreases toward the second electrode **20** side. That is, the plurality of protrusions **80** are shaped so that the cross-sectional area in the direction parallel to the extending direction of the first electrode **10** gradually decreases toward the second electrode **20** side.

The protrusion **80** can be shaped like e.g. a hemisphere as shown in FIGS. **1**A and **1**B.

However, the shape of the protrusion **80** is not limited to a hemisphere.

FIG. **2** is a schematic sectional view for illustrating an alternative shape of the protrusion **80**.

As in the organic electroluminescent element **1***b* shown in FIG. **2**, the protrusion **80** can also be shaped like a quadrangular prism.

Furthermore, the protrusion **80** can be configured to have an arbitrary shape such as a cone, prism, truncated cone, truncated prism, hemisphere, and semi ellipsoid.

The protrusion **80** is shaped so that the cross-sectional area in the direction parallel to the surface **10***a* of the first electrode **10** gradually decreases toward the second electrode **20** side. Thus, a reflective surface **20***a* can be formed in the second electrode **20**.

Light propagated with reflection inside the first electrode **10** and the organic light emitting layer **30** is introduced into the protrusion **80** and is incident on the reflective surface **20***a*. The reflective surface **20***a* is inclined with respect to the surface **10***a* of the first electrode **10**. Thus, the light incident on the reflective surface **20***a* is reflected toward the substrate **60** side. Accordingly, the light confined inside the first electrode **10** and the organic light emitting layer **30** can be extracted to the outside. Thus, the light extraction efficiency can be improved.

The arrangement configuration of the protrusions **80** is not particularly limited. For instance, a plurality of protrusions **80** can be regularly arranged like a matrix and the like, or can be arranged in an arbitrary configuration.

The plurality of protrusions **80** may be equally sized, or may include protrusions **80** with different sizes.

The organic electroluminescent element **1**, is illustrated in FIGS. **1**A and **1**B includes a substrate **60** on the opposite side of the first electrode **10** from the side provided with the organic light emitting layer **30**. That is, the first electrode **10** is provided between the substrate **60** and the organic light emitting layer **30**. The substrate **60** is transmissive to light emitted from the organic light emitting layer **30**. The substrate **60** can be made of e.g. transmissive glass such as quartz glass, alkali glass, and alkali-free glass. Alternatively, the substrate **60** can also be made of e.g. transmissive resin such as polyethylene terephthalate, polycarbonate, polymethyl methacrylate, polypropylene, polyethylene, amorphous polyolefin, and fluorine-based resin. The refractive index of the substrate **60** is e.g. 1.4 or more and 1.7 or less.

Furthermore, the organic electroluminescent element **1**, **1***a* includes a plurality of microlenses **90** on the surface of the substrate **60** on the opposite side from the side provided with the first electrode **10**. For instance, the microlens **90** can be shaped like a hemisphere. The height dimension (the length along the thickness direction of the substrate **60**) of the microlens **90** can be set to e.g. 1 micrometer (μm) or more and 50 micrometers (μm) or less. In this case, the diameter dimension of the microlens **90** is 2 micrometers (μm) or more and 100 micrometers (μm) or less. However, the shape and dimension of the microlens **90** are not limited to those illustrated, but can be appropriately changed.

The plurality of microlenses **90** can be formed by photolithography technique and the like. However, use of photolithography technique involves what is called the thin film process in which the film thickness of the film to be processed is 10 micrometers (μm) or less. In this case, if the diameter of the microlens **90** is larger than 2 micrometers (μm), the height dimension of the microlens **90** needs to be set to approximately 1 micrometer (μm) in order to achieve an ideal lens shape of the microlens **90**. Then, cracks may occur due to the internal stress of the thin film. This makes it difficult to process the microlens **90**. Thus, if photolithography technique and the like are used, microlenses **90** having an appropriate shape are difficult to form stably.

In contrast, if a microlens sheet with a plurality of microlenses **90** arranged like a matrix is affixed, microlenses **90** having an appropriate shape can be easily provided.

In the illustrated example, a plurality of microlenses **90** are provided. However, an arbitrary optical element capable of changing the traveling direction of light may be provided. For instance, other optical elements can be provided by using another optical film such as a lenticular lens sheet and a sheet having a pyramid structure.

FIG. **3** is a graph illustrating the light extraction efficiency in the case of providing a protrusion **80** shaped like a hemisphere.

The horizontal axis of FIG. **3** represents the opening ratio. That is, it represents the ratio of the area of the region not provided with the protrusion **80** to the area of the surface of the first electrode **10** or to the area of the surface of the organic light emitting layer **30**.

The vertical axis of FIG. **3** represents the light extraction efficiency.

FIG. **3** shows an example of ray-trace simulation results for the light extraction efficiency.

The condition of the simulation was set as follows.

For the first electrode **10**, the refractive index was set to 1.8, and the thickness dimension was set to 100 nanometers (nm). For the organic light emitting layer **30**, the refractive index was set to 1.8, and the thickness dimension was set to 100 nanometers (nm). The protrusion **80** was shaped like a hemisphere having a refractive index of 1.8 and a diameter dimension of 3 micrometers (μm). The microlens **90** was shaped like a hemisphere having a refractive index of 1.5 and a diameter dimension of 30 micrometers (μm). The wavelength of light generated in the organic light emitting layer **30** was set to 525 nanometers (nm).

Then, the opening ratio was changed, and the light extraction efficiency for each case was calculated.

In FIG. **3**, "A" represents the case where the protrusion **80** and the microlens **90** are not provided. "B" represents the case where the protrusion **80** is not provided but the microlens **90** is provided. "C" represents the case where the protrusion **80** is provided but the microlens **90** is not provided. "D" represents the case where the protrusion **80** and the microlens **90** are provided.

As seen from "A" and "C", the light extraction efficiency can be improved by providing the protrusion **80**. Furthermore, as seen from "C" and "D", as the opening ratio is made smaller, i.e., as the number of protrusions **80** is made larger, the light extraction efficiency can be made higher. Furthermore, as seen from "D", the light extraction efficiency can be further improved by providing the protrusion **80** and the microlens **90**.

FIG. **4** is a graph illustrating the light extraction efficiency in the case of providing a protrusion **80** shaped like a quadrangular prism.

The horizontal axis of FIG. **4** represents the opening ratio. That is, it represents the ratio of the area of the region not provided with the protrusion **80** to the area of the surface of the first electrode **10** or to the area of the surface of the organic light emitting layer **30**.

The vertical axis of FIG. **4** represents the light extraction efficiency.

FIG. **4** shows an example of ray-trace simulation results for the light extraction efficiency.

The condition of the simulation was set as follows.

For the first electrode **10**, the refractive index was set to 1.8, and the thickness dimension was set to 100 nanometers (nm). For the organic light emitting layer **30**, the refractive index was set to 1.8, and the thickness dimension was set to 100 nanometers (nm). The protrusion **80** was shaped like a quadrangular prism having a refractive index of 1.8 in which the length of one side of the square base is 3 micrometers (μm) and the height dimension is 3 micrometers (μm). The microlens **90** was shaped like a hemisphere having a refractive index of 1.5 and a diameter dimension of 30 micrometers (μm). The wavelength of light generated in the organic light emitting layer **30** was set to 525 nanometers (nm).

Then, the opening ratio was changed, and the light extraction efficiency for each case was calculated.

In FIG. **4**, "A**1**" represents the case where the protrusion **80** and the microlens **90** are not provided. "B**1**" represents the case where the protrusion **80** is not provided but the microlens **90** is provided. "C**1**" represents the case where the protrusion **80** is provided but the microlens **90** is not provided. "D**1**" represents the case where the protrusion **80** and the microlens **90** are provided.

As seen from "A**1**" and "C**1**", the light extraction efficiency can be improved by providing the protrusion **80**. Furthermore, as seen from "C**1**" and "D**1**", as the opening ratio is made smaller, i.e., as the number of protrusions **80** is made larger, the light extraction efficiency can be made higher. Furthermore, as seen from "D**1**", the light extraction efficiency can be further improved by providing the protrusion **80** and the microlens **90**.

Furthermore, as seen from "C" and "D" in FIG. **3** and "C**1**" and "D**1**" in FIG. **4**, the light extraction efficiency is changed with the shape of the protrusion **80**.

That is, if the protrusion **80** is shaped so as to form a flat reflective surface **20***a* in the second electrode **20**, the light extraction efficiency can be further improved.

For instance, the protrusion **80** is preferably shaped like such as a prism and truncated prism.

FIG. **5** is a graph illustrating the light extraction efficiency in the case of providing a protrusion **80** shaped like a quadrangular prism.

The horizontal axis of FIG. **5** represents the height dimension of the protrusion **80**.

The vertical axis of FIG. **5** represents the light extraction efficiency.

FIG. **5** shows an example of ray-trace simulation results for the light extraction efficiency.

The condition of the simulation was set as follows.

For the first electrode **10**, the refractive index was set to 1.8, and the thickness dimension was set to 100 nanometers (nm). For the organic light emitting layer **30**, the refractive index was set to 1.8, and the thickness dimension was set to 100 nanometers (nm). The protrusion **80** was shaped like a quadrangular prism having a refractive index of 1.8 in which the length of one side of the square base is 3 micrometers (μm). The microlens **90** was shaped like a hemisphere having a refractive index of 1.5 and a diameter dimension of 30 micrometers (μm). The wavelength of light generated in the organic light emitting layer **30** was set to 525 nanometers (nm).

Then, the height dimension of the protrusion **80** was changed, and the light extraction efficiency for each case was calculated.

In FIG. **5**, "A**2**" represents the case where the protrusion **80** and the microlens **90** are not provided. "B**2**" represents the case where the protrusion **80** is not provided but the microlens **90** is provided. "C**2**" represents the case where the protrusion

80 is provided but the microlens 90 is not provided. "D2" represents the case where the protrusion 80 and the microlens 90 are provided.

As seen from "A2" and "C2", the light extraction efficiency can be improved by providing the protrusion 80. Furthermore, as seen from "D2", the light extraction efficiency can be further improved by providing the protrusion 80 and the microlens 90. Furthermore, as seen from "C2" and "D2", if the height dimension of the protrusion 80 is set to 1 micrometer (μm) or more and 3 micrometers (μm) or less, the light extraction efficiency can be further improved.

The length of one side of the base of the protrusion 80 is 3 micrometers (μm). Thus, if the ratio of the length of one side of the base to the height is set to 3:1 to 1:1, the light extraction efficiency can be further improved. For instance, in the case where the length of one side of the base of the protrusion 80 is 30 micrometers (μm), if the height is set to 10 micrometers (μm) or more and 30 micrometers (μm) or less, the light extraction efficiency can be further improved.

In the present case, the base of the protrusion 80 is a square with the length L of one side being 3 micrometers (μm). Thus, the maximum length L_{MAX} at the base is the length of the diagonal, which is 4.2 micrometers (μm).

The maximum length at the base of the protrusion 80 is denoted by L_{MAX}, and the height of the protrusion 80 is denoted by H. Then, the light extraction efficiency can be further improved by setting $1.4 \le L_{MAX}/H \le 4.2$. The unit of L_{MAX} is micrometers (μm). The unit of H is micrometers (μm).

This is the case where the base is a square. However, a similar effect is achieved in the case where the base is shaped differently.

That is, the maximum length at the surface (base) of the protrusion 80 on the first electrode 10 side is denoted by L_{MAX}, and the height of the protrusion 80 is denoted by H. Then, the light extraction efficiency can be further improved by setting $1.4 \le L_{MAX}/H \le 4.2$.

Here, the maximum length L_{MAX} at the surface (base) of the protrusion 80 on the first electrode 10 side is the maximum length of a line segment formed at the surface (base) of the protrusion 80 on the first electrode 10 side.

For instance, in the case where the surface (base) of the protrusion 80 on the first electrode 10 side is circular, the maximum length L_{MAX} is the length of the diameter. In the case where the surface (base) of the protrusion 80 on the first electrode 10 side is quadrangular, the maximum length L_{MAX} is the length of the diagonal. In the case where the surface (base) of the protrusion 80 on the first electrode 10 side is elliptic, the maximum length L_{MAX} is the length of the long axis.

Here, the maximum length L_{MAX} at the surface (base) of the protrusion 80 on the first electrode 10 side does not need to be a length inside the surface (base) of the protrusion 80 on the first electrode 10 side.

For instance, in the case where the surface (base) of the protrusion 80 on the first electrode 10 side is triangular, the maximum length L_{MAX} is the length of one side of the triangle.

Second Embodiment

FIGS. 6A and 6B are schematic sectional views illustrating organic electroluminescent elements according to a second embodiment.

FIG. 6A shows the case where the protrusion 80 is provided between the first electrode 10 and the organic light emitting layer 30.

FIG. 6B shows the case where the protrusion 80 is provided between the organic light emitting layer 30 and the second electrode 20.

As shown in FIGS. 6A and 6B, the organic electroluminescent element 11, 11*a* includes the first electrode 10, the second electrode 20, an organic light emitting layer 30, a protrusion 80, and an optical path control layer 70. Furthermore, like the aforementioned organic electroluminescent element 1, 1*a*, the organic electroluminescent element 11, 11*a* may further include a substrate 60 and a microlens 90.

In the illustrated example, the protrusion 80 shaped like a hemisphere is provided. However, the shape of the protrusion 80 is not limited to a hemisphere.

The protrusion 80 can be configured to have an arbitrary shape such as a cone, prism, truncated cone, truncated prism, hemisphere, and semi ellipsoid.

The organic electroluminescent element 11, 11*a* is different from the aforementioned organic electroluminescent element 1, 1*a* in that the optical path control layer 70 is further provided.

The optical path control layer 70 is provided on the opposite side of the first electrode 10 from the side provided with the organic light emitting layer 30. In the example illustrated in FIGS. 6A and 6B, the optical path control layer 70 is provided between the first electrode 10 and the substrate 60.

The optical path control layer 70 is transmissive to light emitted from the organic light emitting layer 30.

The material of the optical path control layer 70 is not particularly limited as long as it is transmissive to light emitted from the organic light emitting layer 30. However, the refractive index of the optical path control layer 70 can be made comparable to the refractive index of the organic light emitting layer 30. If the refractive index of the optical path control layer 70 is comparable to the refractive index of the organic light emitting layer 30, light can be smoothly introduced between the organic light emitting layer 30 side and the optical path control layer 70.

For instance, the refractive index of the optical path control layer 70 is denoted by n_2, and the refractive index of the organic light emitting layer 30 is denoted by n_1. Then, the refractive indices can be set as $n_1 \times 0.9 \le n_2 \le n_1 \times 1.1$.

As described above, the refractive index of the protrusion 80 can be made comparable to the refractive index of the organic light emitting layer 30. Thus, the refractive index of the optical path control layer 70, the refractive index of the organic light emitting layer 30, and the refractive index of the protrusion 80 can be made comparable.

In this case, the material of the optical path control layer 70 can be made identical to the material of the protrusion 80. The thickness dimension of the optical path control layer 70 can be set to e.g. 1 micrometer (μm) or more and 100 micrometers (μm) or less.

Next, the function of the optical path control layer 70 is further described.

The organic electroluminescent element 1, 1*a* illustrated in FIGS. 1A and 1B does not include the optical path control layer 70.

Thus, as shown in FIGS. 1A and 1B, light propagates while being reflected between the substrate 60 and the second electrode 20. In this case, the distance between the substrate 60 and the second electrode 20 is short. Thus, the number of times of reflection relative to the propagation distance of light is large. As the number of times of reflection becomes larger, loss due to reflection becomes higher.

For instance, if the reflectance of the second electrode 20 is 90%, light can be reflected only approximately 10 times. Thus, the lateral propagation distance of light is approximately 1 to 3 μm. In this case, unless the width dimension and the pitch dimension of the protrusions **80** are made comparable to the lateral propagation distance of light, the propagating light of the emitted light does not enter the protrusion **80**. For instance, in the case where the optical path control layer **70** is not provided as in the organic electroluminescent element **1**, **1**a according to the first embodiment, if the width dimension and the pitch dimension of the protrusions **80** are approximately 1 to 3 micrometers (μm), the width dimension and the pitch dimension of the protrusions **80** are comparable to the lateral propagation distance of light. Thus, the light extraction efficiency can be improved. In this case, the protrusion **80** can be formed by a semiconductor manufacturing process such as photolithography technique.

As shown in FIGS. **6**A and **6**B, also in the case where the optical path control layer **70** is provided, light propagates while being reflected between the substrate **60** and the second electrode **20**. However, in the case where the optical path control layer **70** is provided, the distance between the substrate **60** and the second electrode **20** is made longer by the amount of the thickness dimension of the optical path control layer **70**. This can decrease the number of times of reflection relative to the propagation distance of light.

As described above, if the reflectance of the second electrode **20** is 90%, light is reflected approximately 10 times. Thus, the lateral propagation distance of light can be made as long as approximately 10 times the film thickness of the optical path control layer **70**. If the lateral propagation distance of light is made longer, the light extraction efficiency can be improved even if the width dimension and the pitch dimension of the protrusions **80** are set to approximately 10 times the film thickness of the optical path control layer **70**. If the width dimension and the pitch dimension of the protrusions **80** can be made longer, the protrusions **80** can be formed by a cost-effective process such as screen printing technique.

FIG. **7** is a graph for illustrating the light extraction efficiency.

FIG. **7** shows an example simulation result for the light extraction efficiency in the configurations shown in No. 1 to No. 4.

The vertical axis of FIG. **7** represents the light extraction efficiency.

The configuration shown in No. 1 corresponds to the case where the protrusion **80** is not provided.

The configuration shown in No. 2 corresponds to the case where the protrusion **80** shaped like a quadrangular prism is provided and the microlens **90** is not provided.

The configuration shown in No. 3 corresponds to the case where a plurality of microlenses **90** are further provided in the configuration shown in No. 1.

The configuration shown in No. 4 corresponds to the case where a plurality of the microlenses **90** are further provided in the configuration shown in No. 2.

The condition of the simulation was set as follows.

For the first electrode **10**, the refractive index was set to 1.8, and the thickness dimension was set to 100 nanometers (nm). For the organic light emitting layer **30**, the refractive index was set to 1.8, and the thickness dimension was set to 100 nanometers (nm). The protrusion **80** was shaped like a quadrangular prism having a refractive index of 1.8 in which the length of one side of the square base is 80 micrometers (μm) and the height dimension is 60 micrometers (μm). A plurality of protrusions **80** were arranged like a matrix (lattice). The dimension between the protrusions **80** was set to 80 micrometers (μm). For the optical path control layer **70**, the refractive index was set to 1.8, and the thickness dimension was set to 100 micrometers (μm). For the substrate **60**, the refractive index was set to 1.5, and the thickness dimension was set to 700 micrometers (μm). The microlens **90** was shaped like a hemisphere having a refractive index of 1.5 and a diameter dimension of 30 micrometers (μm). The microlenses **90** were arranged in hexagonal closest packing, with the packing ratio being 82%. The wavelength of light generated in the organic light emitting layer **30** was set to 525 nanometers (nm).

As shown in No. 2 in FIG. **7**, if the protrusion **80** is provided, the light extraction efficiency can be improved as compared with that shown in No. 1 in which the protrusion **80** is not provided. Furthermore, the light extraction efficiency can be improved also by setting the width dimension of the protrusion **80** to 80 micrometers (μm). Thus, an organic electroluminescent element having high light emission efficiency can be obtained cost-effectively using a method such as screen printing technique.

Furthermore, as shown in No. 4 in FIG. **7**, if a plurality of microlenses **90** are further provided, the light extraction efficiency can be further improved.

FIG. **8** is a graph for illustrating the relationship between the refractive index of the protrusion **80** and the light extraction efficiency. In FIG. **8**, "E" represents the case of including the microlens **90**, and "F" represents the case of not including the microlens **90**.

The condition of the simulation was set similarly to the case of FIG. **7**. The refractive index of the organic light emitting layer **30** was fixed to 1.8.

The microlens **90** was shaped like a hemisphere having a diameter dimension of 3 micrometers (μm).

Here, as described above, the refractive index of the protrusion **80** is denoted by n, and the refractive index of the organic light emitting layer **30** is denoted by n_1. Then, the refractive indices can be set as $n_1 \times 0.9 \leq n \leq n_1 \times 1.1$.

That is, the refractive index n of the protrusion **80** can be set as $1.62 \leq n \leq 1.98$.

If the refractive index n of the protrusion **80** is set as described above, the light extraction efficiency can be improved as shown in "E" and "F" in FIG. **8**.

Third Embodiment

FIGS. **9**A and **9**B are schematic sectional views illustrating organic electroluminescent elements according to a third embodiment.

FIG. **9**A shows the case where the protrusion **80** is provided between the first electrode **10** and the organic light emitting layer **30**.

FIG. **9**B shows the case where the protrusion **80** is provided between the organic light emitting layer **30** and the second electrode **20**.

As shown in FIGS. **9**A and **9**B, the organic electroluminescent element **21**, **21**a includes a first electrode **10**, a second electrode **20**, an organic light emitting layer **30**, a protrusion **80**, and an optical path control layer **70**. Furthermore, like the aforementioned organic electroluminescent element **1**, **1**a, the organic electroluminescent element **21**, **21**a may further include a microlens **90**.

In the illustrated example, the protrusion **80** shaped like a hemisphere is provided. However, the shape of the protrusion **80** is not limited to a hemisphere.

The protrusion **80** can be configured to have an arbitrary shape such as a cone, prism, truncated cone, truncated prism, hemisphere, and semi ellipsoid.

The organic electroluminescent element **21**, **21**a is different from the aforementioned organic electroluminescent element **11**, **11**a in that the substrate **60** is omitted.

Alternatively, the refractive index of the substrate **60** is made comparable to the refractive index of the optical path control layer **70**.

In the case of the organic electroluminescent element **21**, **21***a*, light propagates while being reflected between the interface **70***a* of the optical path control layer **70** on the side provided with the microlens **90**, and the second electrode **20**. In this case, the distance between the interface **70***a* and the second electrode **20** can be made longer. This can decrease the number of times of reflection relative to the propagation distance of light. As described above, if the reflectance of the second electrode **20** is 90%, light is reflected approximately 10 times. Thus, the lateral propagation distance of light is made as long as approximately 10 times the film thickness of the optical path control layer **70**. If the lateral propagation distance of light is made longer, the light extraction efficiency can be improved even if the width dimension and the pitch dimension of the protrusions **80** are set to approximately 10 times the film thickness of the optical path control layer **70**. In this case, the protrusions **80** can be formed by a cost-effective process such as screen printing technique.

The organic electroluminescent elements described in the above first to third embodiments can be used in a light emitting device. The light emitting device including the organic electroluminescent element described in the first to the third embodiments has higher brightness for the same input electrical power, or lower input electrical power for the same brightness. As described below, besides the light emitting unit including the organic electroluminescent element, the light emitting device may include a driving unit and a control unit.

FIG. **10** is a schematic view for illustrating a light emitting device **111**.

As shown in FIG. **10**, the light emitting device **111** includes a light emitting unit **111***a*, a driving unit **111***b*, and a control unit **111***c*.

The light emitting unit **111***a* includes a plurality of the aforementioned organic electroluminescent elements **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a*. The arrangement configuration of the organic electroluminescent elements **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a* is not particularly limited. For instance, as illustrated in FIG. **10**, it is possible to use a regular arrangement. Alternatively, it is also possible to use a non-regular arbitrary arrangement. Furthermore, the number of organic electroluminescent elements **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a* is not limited to that illustrated, but can be appropriately changed. The number of organic electroluminescent elements **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a* may be one.

The driving unit **111***b* can be configured to include e.g. a driving circuit for applying a current to each organic electroluminescent element **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a* or all the organic electroluminescent elements **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a*.

For instance, in the case where the light emitting device **111** is a display device, the driving unit **111***b* can be configured to apply a current to each organic electroluminescent element **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a*.

Alternatively, for instance, in the case where the light emitting device **111** is an illumination device, the driving unit **111***b* can be configured to apply a current to all the organic electroluminescent elements **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a*.

The configuration of driving by the driving unit **111***b* is not limited to those illustrated, but can be appropriately changed depending on the purpose and the like of the light emitting device **111**.

The control unit **111***c* can be configured to include e.g. a control circuit for controlling the driving unit **111***b*.

Here, known techniques are applicable to the components other than the aforementioned organic electroluminescent element **1**, **1***a*, **1***b*, **11**, **11***a*, **21**, **21***a*. Thus, the detailed description on the light emitting unit **111***a*, the driving unit **111***b*, and the control unit **111***c* is omitted.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the invention. Moreover, above-mentioned embodiments can be combined mutually and can be carried out.

What is claimed is:

1. An organic electroluminescent element comprising:

a first electrode;

a second electrode provided opposite to the first electrode;

an organic light emitting layer provided between the first electrode and the second electrode; and

a protrusion provided at least one of between the first electrode and the organic light emitting layer and between the organic light emitting layer and the second electrode; and

an optical path control layer provided on an opposite side of the first electrode from a side provided with the organic light emitting layer,

a formula

$$n_1 \times 0.9 \le n_2 \le n_1 \times 1.1$$

is satisfied, where n_2 is a refractive index of an optical path control layer, and n_1 is a refractive index of the organic light emitting layer.

2. The element according to claim **1**, wherein the protrusion is shaped so that cross-sectional area in a direction parallel to an extending direction of the first electrode gradually decreases toward a side of the second electrode.

3. The element according to claim **1**, wherein a formula

$$1.4 \le L_{MAX}/H \le 4.2$$

is satisfied, where L_{MAX} is maximum length of a surface of the protrusion on a side of the first electrode, and H is height of the protrusion.

4. The element according to claim **1**, wherein a formula

$$n_1 \times 0.9 \le n \le n_1 \times 1.1$$

is satisfied, where n is a refractive index of the protrusion, and n_1 is a refractive index of the organic light emitting layer.

5. The element according to claim **1**, wherein the protrusion is transmissive to light emitted from the organic light emitting layer.

6. The element according to claim **1**, wherein the protrusion is insulative.

7. The element according to claim **1**, wherein the protrusion is conductive.

8. The element according to claim **7**, wherein conductivity of the protrusion is higher than conductivity of the organic light emitting layer.

9. The element according to claim **1**, wherein the protrusion is provided in a plurality, and the plurality of protrusions are spaced from each other.

10. The element according to claim **1**, wherein the protrusion includes at least one of SiN_x and a polymer resin.

11. The element according to claim **1**, wherein the protrusion includes a polymer resin and a particle having a higher refractive index than a refractive index of the polymer resin.

12. The element according to claim **1**, wherein the optical path control layer has a thickness dimension of 1 micrometer (μm) or more and 100 micrometers (μm) or less.

13. The element according to claim **1**, wherein the optical path control layer is transmissive to light emitted from the organic light emitting layer.

14. The element according to claim **1**, wherein a material of the optical path control layer is a same as a material of the protrusion.

15. A light emitting device comprising:

an organic electroluminescent element including:

a first electrode;

a second electrode provided opposite to the first electrode;

an organic light emitting layer provided between the first electrode and the second electrode;

a protrusion provided at least one of between the first electrode and the organic light emitting layer and between the organic light emitting layer and the second electrode; and

an optical path control layer provided on an opposite side of the first electrode from a side provided with the organic light emitting layer,

a formula

$$n1\times0.9\leq n2\leq n1\times1.1$$

is satisfied, where n2 is a refractive index of an optical path control layer, and n1 is a refractive index of the organic light emitting layer,

a driving unit configured to apply a current to the organic electroluminescent element; and

a control unit configured to control the driving unit.

16. The device according to claim **15**, wherein the protrusion is shaped so that cross-sectional area in a direction parallel to an extending direction of the first electrode gradually decreases toward a side of the second electrode.

17. The device according to claim **15**, wherein a formula

$$1.4\leq L_{MAX}/H\leq4.2$$

is satisfied, where L_{MAX} is maximum length of a surface of the protrusion on a side of the first electrode, and H is height of the protrusion.

18. The device according to claim **15**, wherein a formula

$$n_1\times0.9\leq n\leq n_1\times1.1$$

is satisfied, where n is a refractive index of the protrusion, and n_1 is a refractive index of the organic light emitting layer.

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